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PREFACE

Japan's extraordinary technological achievements over the past two decades have prompted lively debates in the United States and abroad about how best to promote the development and application of technology. These debates ultimately all come down to one basic issue — the secret of Japan's success. Has government policy made a major contribution to Japan's technological achievements or are they primarily due to the vitality of Japanese industry?

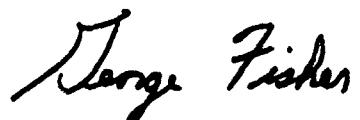
This question has been the subject of countless books, papers and conferences. Missing from the outpouring of ideas about Japan's industrial policy and management practices, however, has been a careful assessment of Japan's technology policy. How does the Japanese government promote technology? Who are the key players? What is their relationship with industry? How do government and the private sector cooperate to advance technological competitiveness?

The Council on Competitiveness is convinced that if the United States is to strengthen its ability to commercialize technology and compete in world markets, it must better understand how government and the private sector in other countries promote technological leadership. It is no secret that Japan's trade and industrial policies have had a major impact on its technological competitiveness. These policies have served to guarantee markets for Japanese producers and thereby encourage the development and commercialization of new technology.

This paper does not attempt to survey Japanese industrial policy. Instead, it is limited to an analysis of Japanese technology policy. It sorts through the fact and fiction surrounding Japan's performance and highlights ten key features of its technology policy. In doing so, it sets the stage for the Council's major forthcoming report, Gaining New Ground: Technology Priorities for America's Future. The report on technology priorities will pick up where this paper leaves off. In it, the Council will identify the critical technologies driving American industry's performance over the coming decade and will make key recommendations for U.S. managers and public officials to improve their performance.

The paper on Japanese technology policy is part of a continuing series that the Council is publishing on various aspects of the competitiveness challenge facing the United States. We hope that these assessments will be useful for policy experts and interested citizens alike.

George Fisher

A handwritten signature in black ink that reads "George Fisher". The signature is fluid and cursive, with "George" on top and "Fisher" below it, slightly overlapping.

Chairman, Council on Competitiveness
Chairman and CEO, Motorola, Inc.

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EXECUTIVE SUMMARY

For the last century, Japanese national policies have placed a high priority on acquiring and developing the technologies needed for economic growth. As a nation, Japan has been extraordinarily successful:

- Japan's non-defense R&D spending has grown so that it is now 50 percent higher than that of the United States as a percentage of GNP.
- Studies of U.S. and Japanese critical technologies show that Japan has reached overall parity with the United States in many key technologies, and is moving ahead. For example, the U.S. Department of Commerce judged that in 12 emerging technologies, Japan is ahead of the United States in five, even in one, and behind in six. The Department of Commerce judged that Japan is advancing relative to the United States in nearly all of the technologies and is losing ground in none.
- In a wide range of technology-intensive industries, the United States has fallen behind Japan. As a result, the U.S. trade deficit with Japan in high-tech products grew from \$5.6 billion in 1981 to \$22.3 billion in 1988.

It is no surprise that Japan is on a steeper technology trajectory because it is investing more intensely in technology and is getting greater returns from these investments. Whether or not the United States can keep pace will have a major impact on U.S. industrial competitiveness and the quality of American jobs into the next century — and the degree of U.S. economic and military independence.

Much can be learned from the policies that have supported Japan's successes. Ten key features are summarized below.

1. Japanese policies recognize that technological leadership is critical to national economic performance and independence. As a resource-poor country, Japan has emphasized the acquisition, development, and use of technology as an engine of economic growth. In recent years, the strategy has been to pursue technologies that are capital- and knowl-

edge-intensive rather than resource-intensive, and to seek leadership in technologies with potential for growth and future advances.

2. Japanese government research emphasizes practical commercial applications. Compared to the United States, Japan funds much less defense, space, and health research, and much more commercially relevant research. Although the U.S. government funds a greater total amount of R&D, Japanese government non-defense R&D spending as a percentage of GNP exceeds that of the United States, and much more Japanese government R&D supports industrial needs.

3. Government technology policies leverage private sector R&D. Many government programs are designed to stimulate private sector R&D. Japan uses a wide variety of policy instruments to promote technology development, many of which lower the financial risk of R&D to companies. These policy instruments include funding of cooperative R&D, subsidized and conditional loans, government investments in high-risk projects, and tax incentives. The Ministry of International Trade and Industry (MITI) also has influence over strategic trade policy, industry structure, and industry's regulatory environment, and uses these levers to promote technology development. Japanese macroeconomic policies have also been supportive. Consequently, the private sector funds more R&D, both as a percentage of all R&D and as a percentage of GNP, than other countries. Industrially-funded R&D is equivalent to about 2.0 percent of GNP in Japan, compared to 1.4 percent of GNP in the United States.

4. Industry is closely involved in the formulation of science and technology policy. MITI maintains close and continual contact with industry, and uses industry associations and advisory committees to review and endorse technology projects and policies. While most research and development is paid for and conducted by industry, the government acts as a facilitator and stimulator. The government generally has a greater role in infant industries, declining industries, and heavily regulated industries than in healthy, internationally competitive industries. Although the influence of private industry has been increasing relative to that of the government, the government maintains a strong role.

5. No single agency serves as "technology czar." Japanese science and technology policy is conducted by many ministries with different goals. The Ministry of Education, Science, and Culture, which funds university research, has the largest share of government R&D spending (47%); followed by the Science and Technology Agency (26%), which focuses on nuclear, space, and advanced technologies; and MITI (13%), which has responsibility for industrial technology. Other ministries have research budgets and promote technology within their areas of jurisdiction.
6. Japanese government agencies often compete to help the private sector develop new technologies. Bureaucratic rivalry is intense among Japanese agencies as they attempt to expand their jurisdiction into new areas of technology. As a result, a multitude of programs sponsored by different agencies have been created to enhance industry's competitiveness in technologies such as biotechnology, electronics, and materials.
7. Government-sponsored cooperative research projects create a "critical mass" of companies that can compete in a technology. Cooperative research projects help to spread risk and share information among companies in pre-commercial, generic technology research and help bring many companies to the leading edge of technology. They do not necessarily produce research breakthroughs, and they stimulate — rather than substitute for — the proprietary research by individual companies, which accounts for the vast majority of corporate research.
8. Japan excels at taking technology from around the world and putting it to work. This expertise is in sharp contrast to the "not-invented-here" syndrome found in the United States. The emphasis on foreign technology acquisition began with the need to catch up to the West. Although the vast majority of technical information now flows through private channels, a variety of government policies and programs, from databases to supportive patent and trade policies, aid the acquisition of foreign technology. Close links between public and private information networks promote sharing of this information.
9. Japan has been increasing its emphasis on basic research, but its priority is still supporting industry. Japan is increasing its emphasis on basic research for three reasons: (1) many leading-edge technologies, such as biotechnology and materials, are increasingly based in science; (2) Japan can no longer rely on advanced research conducted in the West;

and (3) there is international pressure on Japan to contribute more to the international pool of knowledge. Much "basic" research in Japan, however, is research that is "basic to industry's future" rather than basic in the U.S. sense of being "without foreseeable applications." The new focus on basic research does not conflict with the mission of supporting Japan's economic development.

10. Japan has initiated international technology programs to relieve political tensions, but these have not yet met with great success. Japan has initiated several international science and technology projects, including the Human Frontier Science Project (a life-sciences research project) and MITI's recently proposed Intelligent Manufacturing Systems Project (which focuses on developing means of communicating among automated machinery) in an attempt to defuse international political friction. However well-intentioned, these projects have met with skepticism in other countries. In addition, Japan has opened its national research laboratories to foreign scientists, but so far relatively few U.S. scientists have taken advantage of the opportunities.

All of these activities take place in the context of a government policy that signals opportunities and protects markets for Japanese industry. Japanese import restrictions and infrastructure projects serve to guarantee important markets for domestic producers, while subsidies, tax incentives and loan programs provide incentives for Japanese industry to invest in and develop technology. These practices have been extensively documented elsewhere and are not the focus of this report.

I. INTRODUCTION

Obtaining, developing, and using technology have been key to Japan's economic "miracle." This trend has been striking in the post-war period, as Japan excelled in increasingly technology-intensive industries, going from textiles and steel to robots, and semiconductors. A large number of U.S. and Japanese studies indicate that Japan's technological capabilities have advanced to a position of parity with the United States, and that Japan is moving ahead in a number of critical fields.¹ While much attention has been paid to Japanese industrial policy and management techniques, relatively little has been paid to the policies influencing the acquisition, development, and use of technology. As the Japanese economy catches up with the West, and as technology becomes an increasingly important driver of economic growth, these policies will grow in importance.

This paper highlights key features of Japanese science and technology policies that have supported Japan's technological success. It does not discuss in detail many related aspects of the Japanese science and technology enterprise, such as private-sector technology strategies, research related to other government missions (such as energy, ocean, and disaster prevention technologies), and Japanese industrial and economic policies.

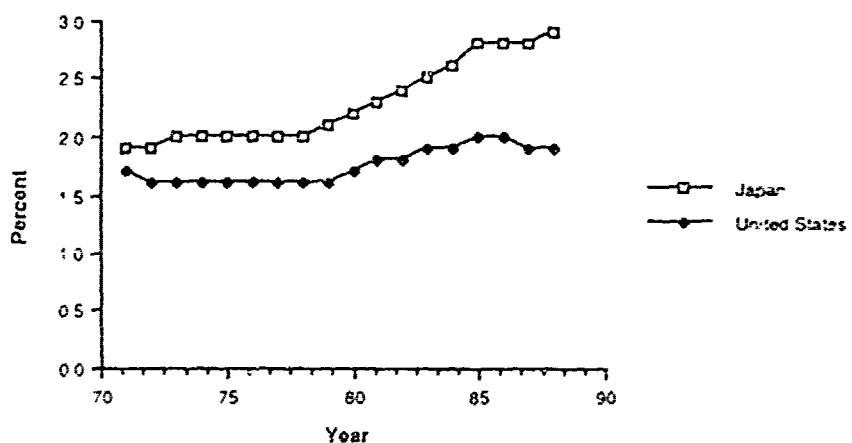
Science and technology policy in Japan has had three main thrusts: 1) government support for research (most of which goes to universities and national research institutes); 2) tax policies, procurement, and other incentives that promote private-sector innovation and R&D; and 3) information gathering and dissemination. In recent years, these have been supplemented by a fourth trend: emphasis on basic research and international aspects of science and technology. This paper will consider each in turn.

II. FRAMEWORK FOR RESEARCH AND DEVELOPMENT

Japan spends only a slightly higher percentage of its GNP on R&D than the United States: 2.9 percent versus 2.8 percent, respectively. But it spends a considerably greater percentage on non-defense R&D, which is more relevant to commercial technologies. (See figure 1.) Japan's R&D investment is also growing at a faster rate than that of the United States.

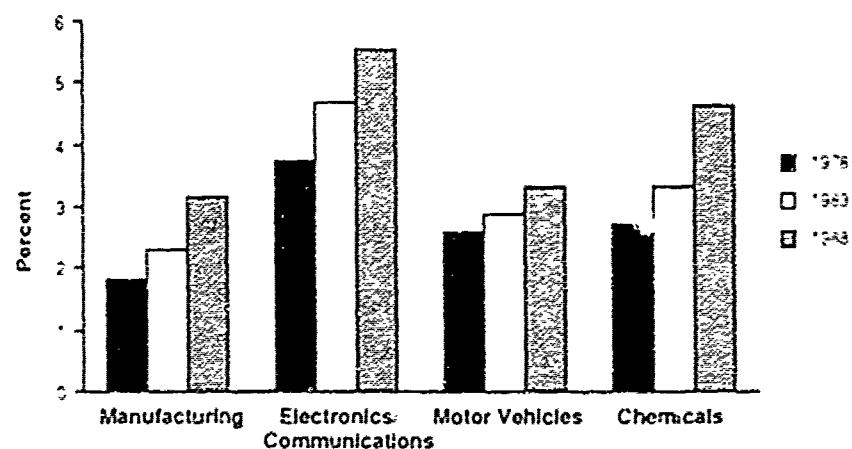
Between 1980 and 1987, Japan's non-defense R&D grew by 69 percent, compared to U.S. growth of 21 percent. Both government and private-sector investment in R&D are increasing, with private-sector funding increasing more rapidly. (See figure 2.)

Figure 1
Non-Defense R&D as Percent of GNP



Source: U.S. National Science Foundation.

Figure 2
Trends in R&D as a Percent of Sales, Various Industries



Source: Japan Management & Coordination Agency

The Japanese government funds a relatively small percentage of Japanese R&D, about 20 percent in 1989, which amounted to approximately \$13 billion.² This is the lowest percentage of national R&D spending among major industrial nations and is in sharp contrast to the popular image of a government-dominated "Japan Inc." By comparison, the U.S. government funds nearly half of all U.S. R&D, amounting to over \$60 billion. When defense R&D (63 percent of U.S. government R&D but less than 5 percent of Japanese R&D) is removed, however, the U.S. and Japanese governments spend similar percentages.³ And as a percentage of GNP, Japanese government non-defense R&D is actually higher than that of the United States.⁴

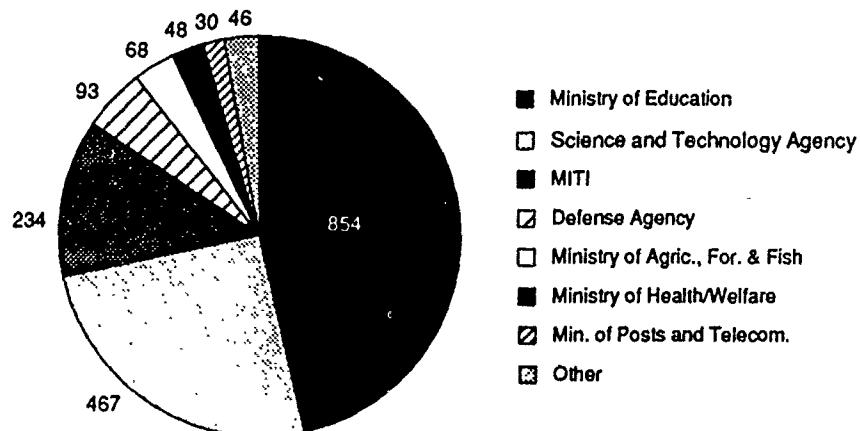
The U.S. and Japanese governments also have very different R&D objectives. A higher percentage of Japanese government R&D funding goes to energy technology and industrial technologies, while a higher percentage of U.S. research goes to health research.⁵

Roles of Government Agencies

Government science and technology funds are administered mainly by three agencies: the Ministry of Education (47 percent), the Science and Technology Agency (STA) (26 percent), and MITI (13 percent).⁶ Although MITI does not control Japanese governmental R&D funding (contrary to the popular perception), its influence on industrial technology is disproportionately large. Most other cabinet ministries and agencies also have small research budgets that are focused in specific areas. (See figure 3.)

Most Ministry of Education spending goes to the national universities, where it is used for basic and applied research, and to costs associated with maintaining university science and engineering programs. University research in Japan is generally weak relative to the United States and Europe,⁷ in spite of its weight in the national science and technology budget.⁸ Nevertheless, the national universities lead the country's basic research. The Ministry also administers significant inter-university programs in basic science, such as high-energy physics. In addition, in 1987 national universities began to carry out joint projects and form joint research centers with industry. In JFY 1989, 480 such projects were planned, with a total budget of \$24 million, of which the Ministry's share was \$4 million.⁹ The amounts associated with those programs have been small, but they constitute an effort by the Ministry to work more cooperatively with industry. In addition, companies have been donating

Figure 3
1989 R&D Funding by Agency (billion yen)



Source: MITI

funds and equipment for university research. In return for this support, companies share in the research results and gain an advantage in recruiting top graduates from the universities.

The Science and Technology Agency's missions are to promote advanced science and technology, and to coordinate national science and technology efforts. Much of STA's R&D effort goes into energy-related projects (especially nuclear energy) and the national space program. It has also been active in other areas of advanced technology, including new materials, lasers, and superconductivity.¹⁰ Even though its primary mission is not economic, STA does consider potential economic benefits as a criterion in choosing many of its R&D projects.¹¹ Some of its programs, such as those in the Exploratory Research for Advanced Technology (ERATO) program are joint projects with industry and universities in advanced generic technologies.¹² STA is also heavily involved in fields that support particular Japanese needs, such as earthquake research. It oversees a number of science and technology-related public corporations, such as the Power Reactor and Nuclear Fuel Development Corporation and the National Space Development Agency of Japan.¹³

Its most important political role is as secretariat to the Prime Minister's Council on Science and Technology, which is the central science and technology policy-making organ.¹⁴ In this capacity, it compiles and submits the national science and technology budget, and coordinates the

R&D efforts carried out by all government agencies. STA's actual control over other agencies' research, however, is limited. In fact, as some STA personnel are on loan from other ministries, such as MITI, these ministries exert a degree of influence over STA's agenda. STA also plays a vital role in building a consensus on future priorities for Japanese science and technology, such as through its Technology Forecast Surveys, and in developing road maps for the development of technology.¹⁴

MITI's primary role is to promote industrial science and technology, mainly through its internal research arm, the Agency of Industrial Science and Technology (AIST). AIST operates a number of research laboratories to promote industrial technology that have a combined budget of around \$1 billion.¹⁵ MITI sponsors several major research projects, which include:

- the Large Scale Project, which includes a number of projects in such diverse areas as computers, databases, hypersonic transport, and robotics technologies;
- the Sunshine Project on new energy technologies;
- the Moonlight Project on energy conservation technologies;
- the R&D project on Medical and Welfare Equipment Technology; and
- the R&D project on Basic Technologies for Future Industries, which supports R&D in new materials, biotechnology, new electronic devices, and superconductivity.

MITI, along with the Ministry of Posts and Telecommunications, also runs the Japan Key Technologies Promotion Center. This center provides equity investments and loans for risky but promising research projects, disbursing about \$180 million in JFY 1989.¹⁶ MITI is also trying to develop regional R&D centers, through the "Technopolis Program."

MITI's influence over technology development is much larger than its modest R&D funding would suggest. MITI has broad jurisdiction over trade and regulatory policy, and can influence industry behavior through the less formal process of "administrative guidance." MITI bureaus maintain close contacts with the corporations under their jurisdiction to formulate policies and shape industries to increase their

competitiveness. MITI is therefore able to use a wide variety of policy instruments to advance industrially important technologies.

While these three agencies provide most of the support for technology, other ministries are important in specific areas. The Ministry of Posts and Telecommunications (MPT), for example, shares with MITI responsibility for the Key Technology Center, and, through its influence over the recently privatized Nippon Telephone and Telegraph (NTT), has some influence over research and procurement by NTT. The Ministry of Agriculture, Forestry, and Fisheries promotes agriculture research and provides support for biotechnology research. The Ministry of Construction influences construction technology through its large public works projects and through building codes. The Ministry of Health and Welfare influences technology development in the pharmaceutical industry through research, drug regulation, pricing policy, and research funding.

Coordination

There are several places where the policies of these agencies are coordinated, at least in principle. The Science and Technology Agency (STA) is charged with coordinating all government scientific and technical activities in its role as secretariat to the cabinet-level Council for Science and Technology.¹⁸ This task includes preparing a budget for science and technology activities by all ministries and agencies. STA, however, is unable to exert significant control over research by larger ministries, in particular MITI and the Ministry of Education.

There are a number of other mechanisms for coordination as well. These include various consultative or advisory bodies that review ministry policies, as well as regular surveys of experts and various forums. These activities serve to keep government policies in line with the needs of industry and universities. The diversity of these mechanisms, however, does not preclude a considerable degree of bureaucratic competition (see next page).

JAPANESE INSTITUTIONAL POLITICS

There is often a mistaken impression outside Japan that the Japanese government has a centralized, highly efficient strategy. Like most organizations, however, Japanese ministries and agencies are vitally interested in expanding their jurisdictions, and turf battles and bureaucratic rivalries abound. Bureaucratic rivalries are especially intense in Japan because of bureaucrats' lifetime relationship with their ministry and because an individual's status in society is tightly linked to the prestige of his organization (rather than his profession or salary). In addition, there is much less political control over the bureaucrats than in the United States. These rivalries are particularly intense in areas of high technology, which are new — and thus uncontested — bureaucratic turf. In some cases the conflicts between ministries result in clear-cut victories or comfortable collaboration, but more often they result in uneasy compromises and overlapping programs. For instance, NTT ran a VLSI program parallel to MITI's efforts, MITI and MPT had competing plans for regional information networks, and STA, MITI, the Ministry of Education, and the Ministry of Transportation all have superconductivity programs.¹⁹

Most disputes are settled according to institutional power rather than official mapping of authority. In spite of STA's official role as coordinator for Japanese science and technology policy, for example, it has relatively little control over MITI or Ministry of Education budgets.

Another important aspect of Japanese institutional politics is that the Ministry of Finance prepares and submits the national budget. Although the Diet must formally approve the budget, it is almost invariably passed without modification. Specific line items (which are much less specific than in the United States) are not debated. Diet members do get involved in resolving disputes between ministries, but their involvement is more limited than in most other countries. This fact has two implications for science and technology policy. First, other ministries must convince the Ministry of Finance Budget Bureau of the soundness of their requests. Second, Diet members have less opportunity to push projects of special interest to them or their constituencies.

These factors have combined to form a policy fabric that is not unified, but nevertheless works fairly well. A positive aspect of the rivalry among ministries is that they are constantly seeking new initiatives to give them an advantage over other ministries, and competing to make the initiatives work.

III. PUSHING COMMERCIAL INNOVATION

The Japanese government has used a wide variety of measures to promote commercial technology in the private sector. These include research at national research institutes (NRIs), cooperative research projects, tax policy, loan programs, government contracting and procurement, and equity purchases in technology development enterprises. Often many of these measures are used simultaneously to promote research in a particular area. In addition, a variety of features of macroeconomic policy and Japan's industrial structure serve to promote private sector research and development.

National Research Institutes

Japan has relatively few government labs compared to the United States, but they focus more on commercial technology. Most U.S. laboratories primarily support U.S. government missions such as defense, health, or energy, and technology transfer to industry is at best an afterthought.²⁰ Many of Japan's National Laboratories were established with the specific purpose of aiding industrial technology.²¹

MITI's Agency for Industrial Science and Technology operates 16 national research institutes (NRIs) that were established in order to support industrial technology development. These had a 1989 total budget of over \$300 million.²² The Science and Technology Agency also runs several laboratories, such as the National Research Institute for Metals and the National Research Institute for Inorganic Materials. Government researchers, along with corporate and university guest researchers, carry out projects at these institutes under the auspices of a variety of programs, such as STA's ERATO program, and AIST's technology projects.

Research at an NRI is often part of a broader effort that includes work at one or more other NRIs and at corporations; in such cases, much of the total funding for the project may come from the private sector. Coordination is provided by the sponsoring agency, in cooperation with leading firms.

*Cooperative Research*²³

Although cooperative research is by no means the dominant form of corporate R&D in Japan and accounts for a low proportion of total

spending, nearly one-third of all corporate research projects in the mid-1980s involved cooperation with other firms or government entities.²⁴ About 90 percent of these were private agreements between two companies, but some involved large consortia. Groups are sometimes organized privately, with one or two lead companies, but in other cases MITI or another agency brings them together. A number of government policies — including favorable tax and regulatory treatment, and rapid depreciation of equipment — encourage cooperative R&D.

MITI does not dictate corporate research agendas, but works in close consultation with corporations to form an industry consensus. By identifying certain areas or technologies as important, this process affects the flow of resources within companies and from the financial community to that technology. Once it is clear that companies are working on a given technology, other companies do not want to risk falling behind by not doing so.

MITI's most important role is coordinating the pre-research stages of a project, at which time the goals, participation, and division of labor are determined. Members of government-initiated or subsidized projects are often selected by the government rather than through an open process. While MITI funding and personnel are often important to the workings and attractiveness of joint research projects, MITI is not, contrary to the popular perception, a major contributor to industrial R&D. Only about 2 percent of private industry's R&D funding comes from the government, and not all of it is in the context of joint research projects.

Research consortia are often portrayed in the United States as the secret to Japanese technological success. Most investigators, however, view these efforts more modestly. Indeed, Japanese companies sometimes look at joint projects as a "cost of doing business." The primary task of consortia is information exchange and coordination of a research agenda, not actual joint research. They are most effective in catch-up situations. Consequently, it is not surprising that the leading company in a field will often refuse to participate. In addition, because consortia are usually made up of competing firms, they tend to concentrate on "nonthreatening and ... low-priority"²⁵ generic technology and applied science rather than research with immediate commercial applications. Nonetheless, a few consortia — like the VLSI and Fifth Generation Computer projects — have been much more ambitious (see following pages).

The most common type of government-supported research consortium is the technology research association. In 1986, these accounted for

around 6 percent of all joint research among Japanese firms and for virtually all projects involving five or more firms.²⁶ These associations are generally temporary and are often dissolved at the end of their project. The system, modeled after a British system, was established in 1961 in order to promote applied research by small- and medium-sized companies.

Thirty years of experience has seen dramatic changes in the use of these associations. Today, large companies are by far the major players in them, and they are usually used for generic research. Some argue that they have simply become devices to funnel government funds to private research, which is not even carried out jointly: "Today Japanese firms seldom use the . . . system unless government funds are introduced to support it; rarely do they conduct research at a common site any longer."²⁷ Nevertheless, government funding tends to account for a small percentage of research associations' budgets.

The other main framework for government-led research consortia are "public policy companies" and budgeted programs. A good example of the former is the Institute for New Generation Computer Technology (ICOT), the home of the Fifth Generation Computer Project. Budgeted programs include the Next Generation Technologies Project and Large-Scale Projects of MITI. These programs fund and coordinate collaborative research in specific areas and appear as line items in the national budget.

Joint research projects combine aspects of cooperation and competition. By making research projects inclusive, agencies can ensure that competition does not suffer. And by promoting competition among firms, the government can encourage innovation.

The Fifth Generation Project

The Fifth Generation Project, a ten-year effort starting in 1981, is another MITI-organized cooperative research project. Bringing together the major firms in the Japanese computer industry, its goal is to bring about a revolution in computing, largely by focusing on artificial intelligence and parallel processing. These represent the "fifth generation" of computers, following computers based on vacuum tubes, transistors, integrated circuits, and very large-scale integrated circuits.

Like the VLSI Project, the Fifth Generation project contains aspects of both cooperation and competition. The core of the project is the Institute for New Generation Computer Technology (ICOT), at which 40 to 50 corporate and MITI researchers, most under the age of 35, work together on high-risk, high-payoff generic technologies. Learning from previous experience, the project chooses young researchers both because of their dynamism and because they are more likely to exchange information more freely. Another change is that there are several foreign researchers at ICOT.

MITI spends about \$40 million per year to fund ICOT. This constitutes the project's entire budget, because firms were unwilling to contribute. Participating companies conduct parallel work on applications and development at their own facilities, comprising another 100 to 150 researchers concentrating on the project.

ICOT disseminates information partly through regular reports and meetings among researchers. Perhaps a more important channel, however, is the rotation of researchers in and out of ICOT itself. This allows for considerable cross-pollination of research efforts.

There is little likelihood that Fifth Generation will meet all its specific goals. However, unlike the VLSI Project, it has produced some important innovations such as a sequential-inference system, and is likely to produce more. Regardless of success or failure, the key benefits to participating corporations are reduced risk of generic research and training for researchers.

Tax Policy

A number of tax measures encourage corporate R&D.²⁸ Allowable deductions include those for (1) private R&D in general, (2) R&D carried out by small- and medium-sized companies, and (3) R&D in specific technical areas.

The general provision allows a firm to deduct 20 percent of R&D expenses beyond the highest previous level (up to a maximum of 10 percent of the total corporate tax). This is similar to the American R&D tax credit, which also bases deductions on marginal increases in R&D. Small- and medium-sized firms can deduct 6 percent of all R&D costs, to a maximum of 15 percent of total corporate tax. Additional deductions can be made for R&D in "base technologies," such as new materials and telecommunications, and in nuclear energy.

One tax provision that differs sharply from those in the United States is radically accelerated depreciation for equipment used in joint research projects. Such equipment can be fully depreciated in one year (in which case its book value drops to 1 yen).²⁹ This reduces considerably the costs of cooperative research, making it more appealing to work with competitors.

Conditional Loans

Conditional loans, a Japanese innovation dating back to the 1930s,³⁰ are loans made to private ventures for specific, high-risk, joint research projects that only need to be paid off in full if the project is successful. These loans may carry below-market rates. For example, the Key Technologies Center will lend up to 70 percent of the costs of a project covering the development phase of key basic technologies at interest rates of 0-5 percent.³¹ Where a project is unsuccessful, only the principal need be repaid, and in some cases the loan is written off by the government. If successful, the firm must pay back the loan with interest. Some authors argue that criteria for success are often so vague that conditional loans need never be paid back, making them resemble outright grants.³² In practice, however, most projects at the Key Technologies Center at least have been judged successful.³³ In any case, conditional loans can make specific projects virtually risk-free.

Financing

The system of "financing for the promotion of industrial technology" provides low-cost financing for technology development. In this system, the Japan Development Bank provides funds at attractive interest rates for the commercialization of important industrial technologies and for the construction of research facilities.³⁴ Funds are available for the construction of demonstration plants or production lines. Approximately 50 percent of the construction costs are eligible for this financing. The budget for this program for JFY 1989 was 750 billion yen.

The Japanese government has also financed joint research ventures by purchasing equity interests in the ventures. A major example is the Japan Key Technologies Center, a quasi-governmental special corporation under the joint management of MITI and the Ministry of Posts and Telecommunications (MPT).³⁵ It is funded partly by government and partly by corporations. The Center provides up to 70 percent of capital for "fundamental research projects" or comprehensive development projects for up to seven years, and up to 50 percent for "Teletopia" or "New Media Community" development programs for up to five years.³⁶ Participating firms retain all patent rights. Any R&D projects established by two or more companies, whether Japanese or foreign-affiliated, are eligible. In JFY 1989, the Center's budget for the capital investment program was \$135 million. In addition, it provided a total of \$43 million in conditional loans of the type described above.

Contracting and Procurement

The government also supports industrial R&D through contract research, in which a private laboratory carries out research of interest to the funding agency. Because universities are publicly funded and there are no major independent or non-profit scientific research centers in Japan, contracted research is almost always carried out by corporations, sometimes in parallel with proprietary research. The total government funding of industry research in JFY 1985 was \$700 million, about 1.6 percent of all industry R&D and 1.2 percent of total R&D.³⁷ These are much smaller percentages than in the United States, where a large amount of defense development work is conducted by industry for the government. Any output of contracted research in Japan is owned by the government and is available to all firms on a non-discriminatory basis. As in the case of research performed at National Research Institutes, contracted research by one company is often done within the context of a partnership or broader consortia.

Procurement plays a relatively small but still important role in technology development in Japan. While government ministries do not have large defense procurement budgets, public corporations, in particular NTT (Nippon Telegraph and Telephone) and NHK (Japan Broadcasting Company), have had a major influence on technology through procurement.

NTT's influence has been strong in microelectronics, computers, and telecommunications. Its huge and predictable purchases from its "family" of firms have encouraged those companies to maintain major R&D efforts.³⁸ Although it has now been officially privatized, the government retains control over 50 percent of all shares, and the Ministry of Posts and Telecommunications (of which it used to be a part) remains closely connected. NHK, meanwhile, has been active over the past 20 years in developing high definition television, and was responsible for a key breakthrough in compressing broadcast information.

Another policy measure that Japan has occasionally used to provide a market pull for advanced technologies has been public leasing corporations. The most notable example is the Japan Electronic Computer Company (JECC).³⁹ This company, modeled after IBM's leasing program, was set up under MITI's jurisdiction, and is owned by Fujitsu, Hitachi, NEC, Toshiba, Mitsubishi, and Oki. It bought computers from manufacturers, leased them to Japanese companies, and then sold them back to the manufacturers at book value. In the process, it provided companies with subsidies and financing. In its early years, it used low-interest loans from the Japan Development Bank. These subsidies helped the undercapitalized Japanese electronics firms break into the highly risky computer market.

JECC accounted for 65 percent of all domestic computers leased or sold in the 1960s and 30 percent in the 1970s.⁴⁰ While no longer essential to the health of the industry, JECC is still active in conducting industry surveys and analyses, and in renting out software. The executive director and a number of other officials of JECC are former MITI officials (through the process of "amakudari"⁴¹), and MITI's role allows it to have a hand in setting prices, standards, and local content requirements.

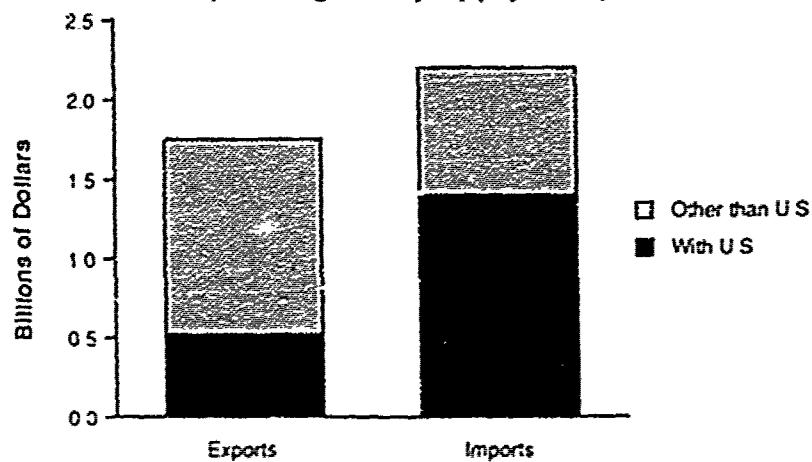
A similar program is now in place for robotics. The Japan Robot Leasing Company (JAROL) was organized in 1982 as a joint venture among 24 robot manufacturers, 10 insurance companies, and 7 general leasing firms, largely with funds borrowed from the Japan Development Bank.⁴² It leases robots and provides technical assistance to small- and medium-sized firms, sometimes in cooperation with the Small Business Finance Center, a government institution that provides loans for robot installation.⁴³

IV. ACQUIRING AND DISSEMINATING TECHNOLOGY

Japan is well known for its demand for foreign technical information and its skill in acquiring it. While it is tempting to consider these to be solely cultural traits, other countries, including the United States in the 19th century, have been similarly aggressive when trying to catch up to other countries. Japan's private sector conducts the bulk of these technology acquisition activities today, but several government policies still play a supportive role.⁴⁴

Private sector technology acquisition is carried out through licensing, joint ventures, and other means. High-technology companies and major trading companies are particularly active. Japan paid \$2.2 billion (mainly to the United States) in licensing fees in JFY 1988, while licensing out only \$1.8 billion worth (mainly to Less Developed Countries).⁴⁵ (See figure 4.) Many Japanese companies have offices or research facilities in the United States located to facilitate access to technology; examples are Shimizu's (a construction company) office near MIT, and Hitachi's installation in Berkeley. Companies also routinely send engineers for additional training at foreign universities. More recently, Japanese companies have increasingly obtained technology by purchasing high-technology companies. In contrast, American firms have been relatively passive about obtaining Japanese technology.

Figure 4
Japan's Technology Imports and Exports
(licensing and royalty payments)



Source: Japan Management & Coordination Agency.

The Japanese government has been active in encouraging the transfer of technical information both domestically and from other countries. It has done this in part to overcome barriers to information flow within the Japanese system, such as the limited mobility of researchers in corporations and universities. The government programs have had a strong emphasis on person-to-person exchanges, abstracting articles, and database services.

There are several major pathways through which the government facilitates information flow, including: (1) science and technology information centers; (2) databases; (3) cooperative research; (4) overseas personnel; (5) publications; and (6) professional societies. In addition, other government policies, such as the mandatory six years of pre-college English language training and various characteristics of the Japanese patent system, facilitate the acquisition of foreign technical information.

Science and Technology Information Centers

Several government and quasi-government organizations have science and technology information centers to gather and spread information in their areas of technical expertise. The most important of these is the Japan Information Center of Science and Technology (JICST), a public corporation under the control of the Science and Technology Agency. It is funded by the Japanese government (about 60 percent of JICST's total budget) and by user fees, and had a JFY 1988 budget of approximately \$86 million and a staff of 327.⁴⁶

JICST's abstracts, indexes, and translates articles from some 14,000 scientific and technical journals (over half of them published outside Japan) in virtually all fields of pure and applied science and engineering. As of May 1988, JICST held 5.6 million document files in Japanese, and 500,000 in English, and planned to prepare an additional 580,000 abstracts in the following fiscal year.⁴⁷ JICST has been active in machine translation, and already uses a version to translate abstracts (mostly English to Japanese). The information gathered is available on-line and in published form.

Databases

Databases are an area where Japan lags behind the United States and is actively trying to catch up. In 1989, 1,964 commercial databases (1,436 of them foreign) were available in Japan, up from only 456 in 1982.

Approximately \$300 million was spent on database services in 1988. Besides JICST, there are many government databases in virtually all areas of science and technology, run by a variety of ministries and agencies, including MITI and the Ministry of Education. National research institutes also compile such databases, with the greatest concentrations in chemicals, materials, and life sciences.⁴⁸ Patent information is available on-line.

MITI has been particularly aggressive in trying to promote domestic databases: in addition to its own services, since 1983 it has published a directory of all databases accessible in Japan. In 1987, it initiated a program that allows database producers to declare 10 percent of database revenue as a loss.⁴⁹ Other government services are tailored to small and regional businesses, offering information and help with technology.⁵⁰

Cooperative Research

Cooperative research, described previously, serves as another conduit for information. Considerable sharing of technical information occurs, particularly in cases when corporate and government researchers work side by side in national research institutes or other labs. Even in joint research projects, where researchers from different corporations or laboratories do not actually work together, regular meetings and memos serve to keep them in contact with each other.

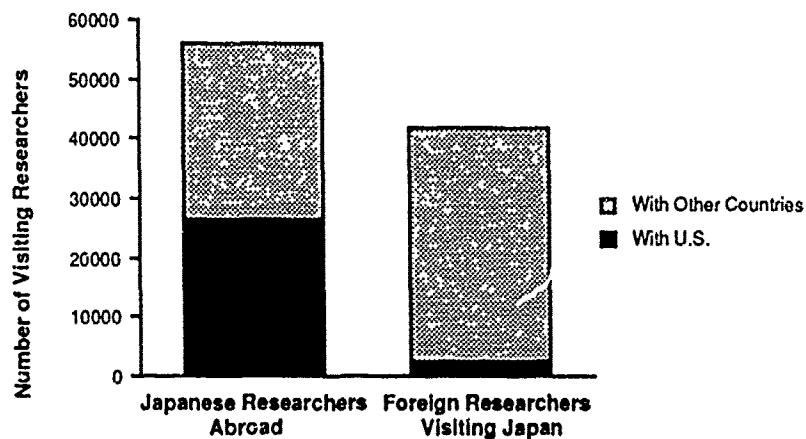
Overseas Personnel

Another major pathway for the flow of technical information is through visiting researchers. In 1986, 55,869 Japanese researchers studied abroad, with 26,334 of them coming to the United States.⁵¹ On the other hand, 43,686 foreign researchers studied in Japan, but only 3,633 came from the United States. (See figure 5.) A significant portion of the Japanese visiting researchers are government-affiliated. For example, of the several hundred Japanese visiting researchers at the U.S. National Institutes of Health and Department of Energy laboratories in FY 1986, about 90 percent were affiliated with non-profits or government.⁵²

Another mechanism is government officials stationed abroad. Officials stationed abroad constitute an informal intelligence network, keeping track of technical developments in their area. Such officials include those in science and commercial sections in embassies and consulates, and in MITI-affiliated organizations such as the New Energy Development Organization (NEDO) and the Japan External Trade

Organization (JETRO). These organizations also work with U.S. consulting firms, which provide another source of information.⁵³

Figure 5
Exchange of Researchers with U.S., Other Countries



Source: Japan Management & Coordination Agency.

Publications

Japanese government agencies and research institutes (as well as universities, companies, industrial organizations, and professional societies) publish numerous technical journals and reports that diffuse technical information developed internally and abroad. JETRO, for instance, has a Japanese publication called "Overseas Project Bulletin" which describes the locations and functions of foreign government research.

Seminars and Societies

Overseas professional seminars also provide a window on external science and technology. Agencies and scientific and professional societies, many of them supported by the government, are active in organizing seminars and conferences, and distributing up-to-date scientific and technical information. Industry associations also actively keep their members informed about pertinent technologies or processes.⁵⁴

Some quasi-public industry organizations have overseas offices, which are charged with keeping abreast of pertinent information on their industries. Often, these organizations have ties to the Japanese government in the form of some funding and employees who are retired bureaucrats.⁵⁵

Other Mechanisms

Especially in the early post-war era, government agencies used a number of other mechanisms to help obtain technology from the West. For instance, MITI used control over imports and licensing of foreign technology to obtain favorable licensing agreements for a number of key computer and semiconductor patents in the 1960s and 1970s.⁵⁶ Technology is also transferred to Japanese industry through military co-development and co-production agreements.

Japanese patent policies tend to do more to disseminate technology than to protect it.⁵⁷ Several features contribute to this tendency: (1) publication of patent applications 18 months after filing; (2) long approval periods (typically four to six years compared with 19 months in the United States); (3) the acceptance of patent flooding (surrounding a patent with closely related trivial patents to interfere with the exercise of the original patent); and (4) the lack of disincentives or remedies for patent piracy. These policies encourage foreign companies to license the technology at low cost, and aid in the internal dissemination of technical information. Japan's intellectual property protection system is expected to improve, however, as Japanese companies become increasingly major owners of intellectual property.⁵⁸

V. TRENDS

As Japan has caught up and begun to pass the West in technology, there have been pressures on Japan to make its research system more open to the rest of the world, and to contribute more to the international pool of scientific knowledge from which it has drawn so much. In addition, partly in response to internal needs, Japan is beginning to place increased importance on creativity and more fundamental research. These trends are slowly reshaping Japanese science and technology policy.

Opening Up Japanese Research

The imbalance between the number of Japanese researchers working in the United States and Europe and the number of Western researchers working in Japanese laboratories is striking. This difference exists even though government research institutes have become quite open to all qualified Western researchers. The imbalance remains, however, largely

because of the perceived low level of basic research carried out in Japanese laboratories, the high cost of living, and language problems.⁵⁹ Nevertheless, the Japanese have been trying to make their laboratories more attractive to foreign researchers by improving facilities, providing financial assistance, and providing training in Japanese language and culture. A major policy change in recent years has been to allow Japanese subsidiaries of American and European companies to participate in government-sponsored projects in Japan,⁶⁰ although the process by which companies are chosen to participate is not open an open one.⁶¹

Technology Diplomacy

"Technology diplomacy" has appeared as an important aspect of Japanese foreign policy.⁶² A major impetus behind technology diplomacy is the desire to defuse international friction of various kinds through initiatives in science and technology. Two recent examples are STA's Frontier Research Program and MITI's Human Frontier Program in life sciences (actually a joint project in spite of the different titles), and MITI's Intelligent Manufacturing Systems Project. These programs were designed to have international participation, and respond to the complaints of other nations that Japan has not contributed adequately to international science and technology. The Human Frontier Science Program even has its secretariat in Strasbourg, France. Western governments and corporations have been skeptical of these projects, suggesting that Japan has selected areas in which it is likely to gain from Western knowledge. The projects have tended to concentrate on areas in which Japanese companies are not at the forefront, such as life sciences and computer software. The Japanese government, on the other hand, defends them as important fields in which each of the prospective participants has specific strengths that will be of value to other participants.

Increasing Basic Research

Japan has found itself at the frontiers of technology with no one to follow at a time when an increasing number of areas of technology depend on advances in science. At the same time, western nations have pressured Japan to stop being a "free rider" in basic research, which is widely viewed as a public good. Prominent expatriate Japanese scientists have criticized the Japanese environment for basic research. As a result, Japan has begun to improve its basic research facilities and to encourage more

basic research. These efforts include the ERATO program, and the establishment of the Japan Prize for scientific achievements. Many of these new initiatives, while involving more basic research than previously done in Japan, are still more applications-oriented than most basic research done in the United States. Most of it is in areas with major commercial applications, and much of it is to be done cooperatively with industry.

VI. A FINAL WORD

The secret of Japan's success in technology is not to be found in any single policy or program. Instead, Japan's successes are due to focused, consistent, and pragmatic policies that support technologies of great commercial importance. The policies recognize that the bulk of technology development can and should be done by private industry, which has the most skill in developing commercial technologies. Thus governmental policies are designed to support — not supplant — industrial R&D. This support takes the form of government funding of pre-competitive R&D and a variety of policies, ranging from tax and macroeconomic to trade policies, which encourage and enable industry to invest in technology. In addition, the government has facilitated information flow to overcome the barriers to exchange among researchers of various affiliations.

Japanese science and technology policies, however, are changing as a result of growing Japanese technological strength, bureaucratic politics, and international pressure. More international cooperation and increased emphasis on creativity and advanced research are two significant trends. Moreover, government agencies are experimenting with new tools, such as direct investment in joint research projects, to encourage innovation. These innovations are partly the result of institutional forces, but they also represent a recognition on the part of the Japanese government that new conditions require new responses. What is likely to remain unchanged, however, is the focus of Japanese science and technology on promoting Japanese industry.

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FOOTNOTES

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³ Government-funded civilian research and development in the United States in FY1990 was about \$24 billion, or about 24% of U.S. civilian R&D. See National Science Board, Science and Engineering Indicators 1989, Washington, U.S. Government Printing Office, 1990, pp.90-95.

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²⁵ Heaton, "The Truth About Japan's Cooperative R&D," p. 37

²⁶ Samuels, Research Collaborations in Japan, p. 39

²⁷ Ibid. p. 41

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²⁹ Samuels, Research Collaboration in Japan.

³⁰ Ibid., p.35.

³¹ NSF/Tokyo RM #161, "Japan Key Technology Center, 1987 Projects and Call for 1988 Proposals."

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³⁹ Anchordoguy, Marie, Computers, Inc: Japan's Challenge to IBM, Cambridge: Harvard University Press, 1989, p.59.

⁴⁰ Ibid.

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